Basalt sills and dikes in or near the proposed DJS 2-14 injection well
discussion by Spencer H. Wood, 1/24/2021

The Willow Field and the proposed DJS 2-14 injection well are within a subsurface section that has stacked basalt sills fed by dikes, all below a depth of 3800 ft [~1.2 seconds on seismic sections]. The area known to be underlain by this field of intrusive basalt is shown in Fig. 1. The question arises whether these discrete basalt layers or dikes have permeability which would qualify them as aquifers (yield of > 2gpm in a well). Seismic sections through the area show that all these basalts are overlain by at least 3800 ft of mostly impermeable lacustrine mudstone of the Chalk Hills and the Glenns Ferry Formations (Fig. 2). While some dikes appear to follow faults, the basalt sills [shown by high amplitude reflections] do not extend above 3800 ft.

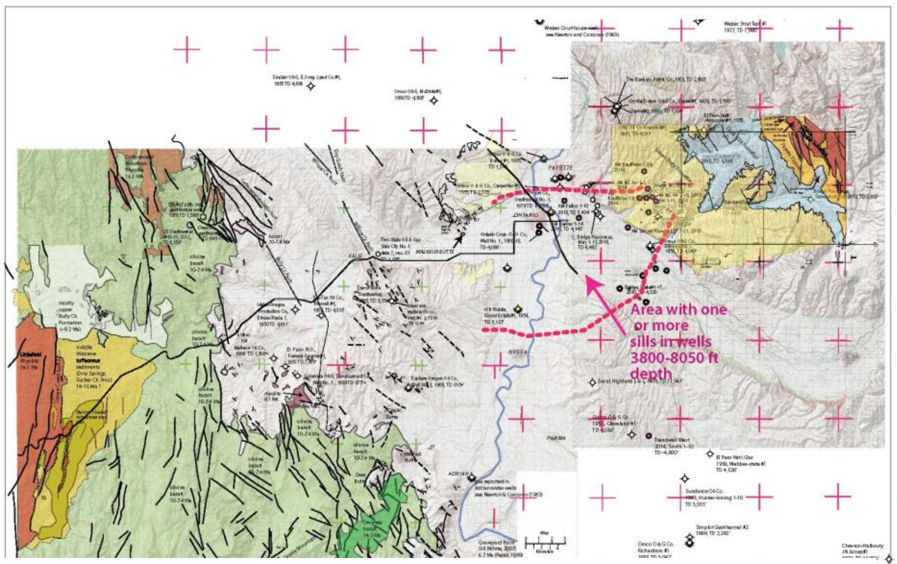


Fig. 1 Map showing area with sills 3800-8050 ft depth

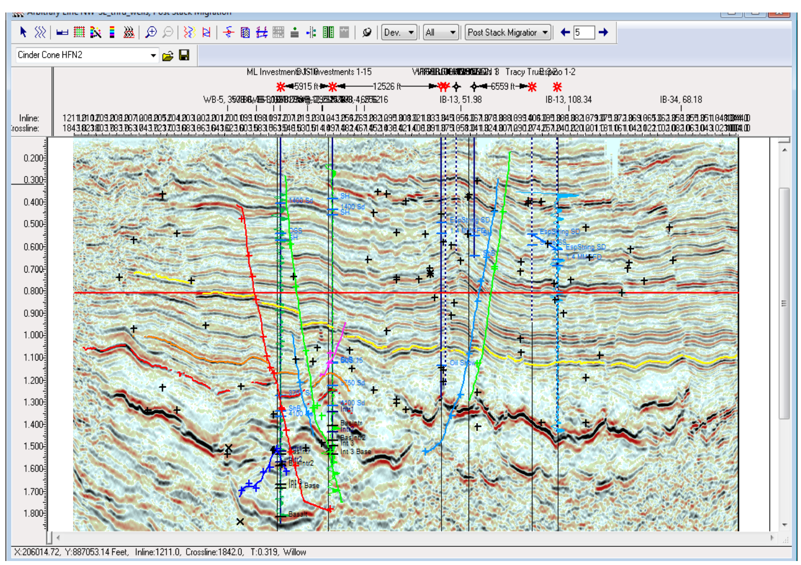


Fig. 2 Seismic section through Willow Field showing field of basalt intrusives below 1.2 seconds (~3,800 ft depth) recognized by high amplitude reflectors.

Our only hydrogeologic evaluation of these intrusive basalts is from reports on the 1979 Ore-Ida Corp. geothermal well drilled to 10,254 ft deep at Ontario, Oregon, 7 miles west of the Willow field. This well contained 6 basalt sills 10-260 ft thick in the sedimentary interval 4500-8050 ft depth (Wood, 2016, 2018). The goal of the well was to produce several hundred gpm of water at 300°F, and they were unable to find such a zone in either the sands or the basalt. As summarized by Austin (1982, p. 2-2).

"Although a thick section of basalt was penetrated, no significant zones of high permeability were demonstrated. Having found inadequate water inflow from the basalt intervals behind the slotted liner, the casing was jet-perforated over several intervals from 6,000 to 7,900 feet. After unloading the hole with nitrogen to 6,800 feet, a water inflow of only 13 gallons per minute (gpm)was measured. When the hole had self-filled, an artesian flow of 1 to 2 gpm was measured [at the surface]. The shut-in pressure was 120 pounds per square inch (psi)."

The 13 gpm was determined from the fluid rise from 6855 to 6091 over a 3 hour period after the well was unloaded. This section contained one basalt sill 7013-7140 in which small temperature-log excursions suggested flow. The 6000-7900 ft section also contained a few hundred feet of medium-grained sandstone, so it is uncertain which layers yielded water, but the basalt likely contributed some of the flow.

While drilling, circulation was lost at 7169. Gardner and Wilson (1980, p. E-12) describe the lost circulation, attributed mostly to increased mud weight.

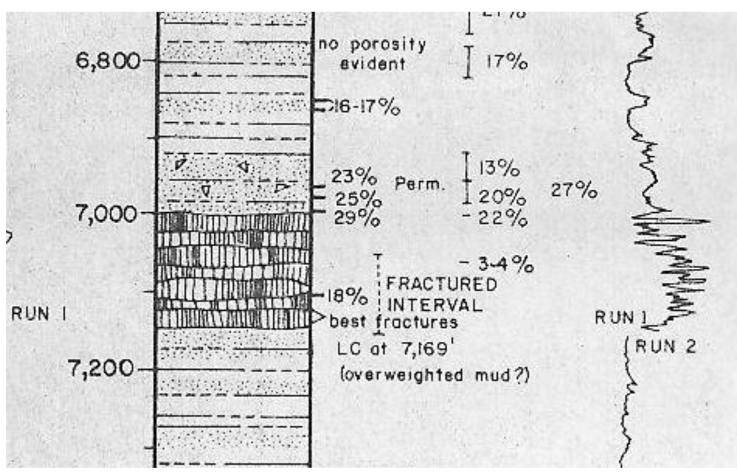
September 21, 1979

New hole was made from 7,156 feet to 7,230 feet. The mud weight was increased to 88 pcf, in order to hold the hole open and remove the accumulated cuttings while reaming. The increased weight caused the drillers to lose circulation at 7,169 feet. Mud weight was reduced from 88 pcf to 82 pcf, lost circulation materials were added, circulation regained, and drilling resumed.

There were a total of 74 feet drilled in 16 hours, averaging 7 feet per hour. Cuttings consisted of sandstone and siltstone, probably from the Lower Idaho Group. Mud return temperatures reached 162°F. GeothermEx personnel: as above.

On a graphic log (Fig. 3) associated with the Gardner and Wilson report, the lower part of the sill is indicated to be fractured, but no information is given for how that was determined.

Fig. 3. Graphic log showing section with sill from 7013-7140, indicating a fractured interval. From file: GLO4098_2.pdf



Austin (1982, p. 3-1) also describes a last effort to induce flow:

"Attempts to improve the flow characteristics of Ore-Ida No. 1 well have met with little success. The most recent action was performed in May 1981 when Los Alamos National Laboratory (LANL) performed a temperature log of the hole and participated in a fluid injection pump test. On May 19, the well was pressured to 1,400 psi at the wellhead and approximately 350 gpm pumped into the 'well in an effort to produce a mini-hydrofrac in the lower zones below 7,000 feet. However, all of the pressurizing fluids were lost at the 5,900- to 6,000-foot interval. An unsuccessful attempt to temporarily seal these perforations with frac balls was made before abandoning the test on May 20."

The sample descriptions indicate that all of this basalt is somewhat hydrothermally altered and secondary mineralization occurs in fractures. As summarized by Austin (1982, 8-26).

"Many samples showed a diffuse greenish color due to partial alteration. Secondary minerals, probably lining fractures, are soft, green serpentine,and chlorite-like materials. traces of quartz, calcite, and possibly zeolite also occur in fractures. No evidence of vesicles, amygdules, or red coloration (characteristic of basalt flow tops) was seen. The texture and the absence of features commonly found in flows suggest that these rocks might be diabases, perhaps present as intrusives rather than as basalt flows."

The only zone that appears somewhat permeable was the lower part of the basalt sill just above the lost circulation zone at 7169. I am unaware if lost circulation occurred while drilling any of the 2010-2015 Bridge Resources or Alta Mesa wells in the Willow field.

From this well data, and consideration of the depth of these basalts they would not be considered aquifers from which useful amounts of water could be extracted. In this situation of hydrothermally altered basalts within more permeable sands these basalt units would be considered aquitards, as are the interbedded mudstones.

References

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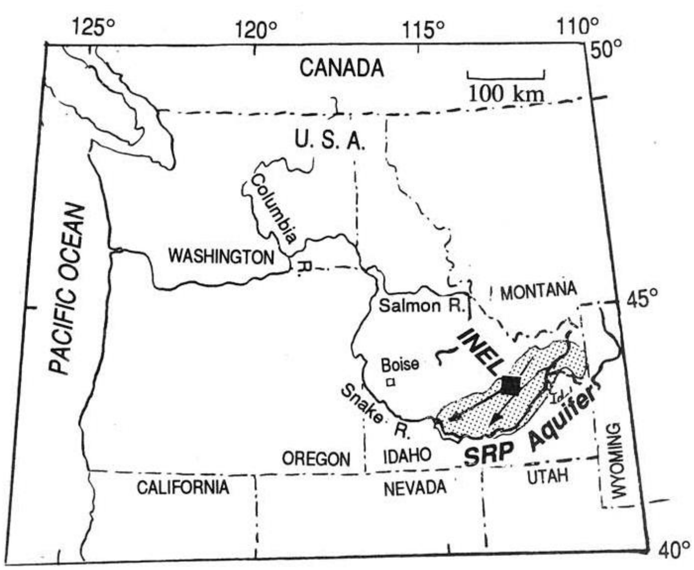
Contrasting high permeability of Quaternary basalt versus low permeability of deeper (hydrothermally altered) Tertiary basalt

Values transmissivity and hydraulic conductivity for the upper 1600 ft of fresh unaltered Quaternary basalt in eastern Idaho are among the highest in the world (Wood and Bennecke, 1994, p. 268; Garabedian, 1992, p. F12). This has led to an incorrect assumption that basalts are permeable. Below 1600 ft, the late Tertiary basalts show increasing amount of propylitic alteration (hydrothermal alteration to chlorite, calcite, quartz, epidote) and secondary zeolite mineralization (Doherty et al., 1979, p. 3; Mann, 1986 p. 4). The diminishing permeability with depth in eastern plain aquifer is best summarized by Welhan and Reed (1997, p. 857).

> The upper basalt–sedimentary sequence comprises what is believed to be the permeable, most actively flowing portion of the aquifer system, which grades downward into older (late Tertiary, early Quaternary) basalt units of lower permeability (Whitehead, 1992). In general, older basalts have lower hydraulic conductivity due to lower fracture density and greater secondary mineral infilling of primary and secondary porosity. These rocks overlie a basement silicic volcanic sequence which in places hosts low-temperature, geothermal waters and which is not considered part of the Snake River Plain aquifer. In borehole INEL-1 (Fig. 3), basalt occurs to a depth of 660 m and is underlain by hydrothermally altered silicic volcanics in which nearly all fracture porosity is filled with secondary mineralization (Mann, 1986). The hydraulic conductivity of basalt from surface to about 490 m in INEL-1 is two to five orders of magnitude higher than the underlying, mineralized Tertiary basalts and silicic volcanics; active circulation of ground water probably does not occur below about 300–600 m depth (Mann, 1986). Similar geologic features have been found in other deep boreholes at INEL, suggesting that the actively circulating portion of the eastern Snake River Plain aquifer is of the order of 60–150 m thick (Barraclough et al., 1967; Lindholm and Vaccaro, 1988). On this basis, the thickness of the Snake River Plain aquifer is less than 1/200th its width, and hence there is justification for modeling it as a two-dimensional flow system (Robertson, 1974; Garabedian, 1992).



ig. 1. Location of the Quaternary-basalt eastern Snake River Plain aquifer. from Wood and Bennecke (1994).

This concept of basalt flow features and fracture porosity [and permeability] greatly diminished with secondary mineralization applies to the deep basalts in many basins. The concept has been tested and surely exceptions found in the extensive investigations beneath nuclear facilities in the western US, particularly groundwater contamination in the Columbia River basalt beneath the Hanford, Washington. But the very high permeability of eastern Snake River basalts should not be generalized to deeper older basalt layers.

References:

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